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THE BANANA WEEVIL[1]

By Silverio M. Cendaña

INTRODUCTION

THREE PLATES

The banana is the most important of all tropical fruits and its future commercial possibilities are practically unlimited, but the banana weevil (*Cosmopolites sordidus* Germ.) is a serious hindrance to its increased production. This insect is the most destructive insect pest of banana, and unless proper precautions as to its control be taken, the production of this fruit for commerce will be seriously hampered.

Cosmopolites sordidus Germ. is a serious pest of banana in almost every country where the plant is cultivated. In the Philippines, besides damaging banana, the beetle is also a serious pest of abaca (*Musa textilis* Nee.). As abaca is the source of the world's best shipping cordage and a Philippine natural monopoly, the damage by the beetle means much financial loss in this crop as well as in banana production.

The adult was first described as *Calandra sordida* in 1824 by Germar (1). The genus *Cosmopolites* was established for this species by Chevrolat in 1885 (2).

In 1916, Mackie (3), in his report, mentioned the insect as the cause of the death of large numbers of abaca and banana plants in Paete, Laguna Province. Today, the Paete abaca industry is practically ruined.

In the Bicol provinces, where abaca is extensively grown, this insect is likewise a cause of serious damage. Large numbers of suckers lose their vigor and wither because of its attack. The only means taken to combat this pest is the use by the people in these regions of the white grub of the beetle for fish bait.

In 1903, Fleutiaux (4) recorded the banana weevil as a serious pest of bananas in Madagascar. Knowles (5) reported the insect as a source of damage to bananas in the Fiji Islands during 1908, and mentioned CS_2 as most effective in killing the insect. He also mentions an ordinance in Fiji requiring banana planters to keep their plantations in proper condition of cultivation as a means of checking the rapid increase of the insect. Jepson in 1911 worked on the insect in Fiji and going to Java in 1914 (6) found some Histerid Beetles which were natural enemies of this insect. These he brought to Fiji, and, by this introduction, he succeeded in considerably reducing the ravages of the insect there.

Fletcher (7) in 1914, published records of this species from Southern India as existing in the regions of Malabar, Coimbatore, Godavari, and Gamjam.

Ballou reported the insect in the Lesser Antilles in 1912 (8).

Jepson (6) recorded the insect as being present in Ceylon, Java, Borneo, New Guinea, Malacca, Saigon, China, Fiji, Raratonga, West Indies, Madagascar, Reunion, Brazil, Sikhim, North Bengal, Pequ, Tenaserrim, Andaman Islands,

[1] Thesis presented for graduation from the College of Agriculture, No. 135; Experiment Station contribution, No. 77.

Sambak, and Seychelles in 1914. Later, in 1916, Ballou (9) recorded the insect in Jamaica, Guadeloupe, Dominica, Martinique and Trinidad in the West Indies, Brazil in South America, the Philippines, Fiji, Borneo, Sumatra, India, Queensland and the Straits Settlement in the East.

In 1918 (10) the introduction into the United States of all parts of banana used for propagating purposes was prohibited due to the appearance in Florida, in 1917, of the banana root borer. The insect is said to have been present in Florida for at least 20 years before that time.

In the same year, experiments in Jamaica (11) were reported to have proven that submerging the plants in water for 48 hours drowned the insects. It was also pointed out that fumigation with CS_2 kills the plant and is, therefore, not advisable to use; and that the charring of banana stocks is inefficient. The statement was also made that good management of the plantations, and keeping of fowls among the plants prevented the insect from producing serious damage.

Froggatt in 1919 (12) recorded the insect as doing some damage to bananas in several localities in New South Wales. He also worked on the life history of the insect.

Moznette in 1920 (13) worked out the life history of the beetle, and described in detail the different stages of its development.

In the Philippines, the insect is found throughout the Islands as evidenced by specimens of it in the Bureau of Science having been collected in Manila by Banks; in Pagsanjan, Laguna by Schültze; in Davao, Mindanao by Weber; and in Iwahig, Palawan by Schültze (14). Although its presence in the Philippines was reported only within the last 20 or 30 years, yet judging from the well-established situation and the island-wide distribution of the beetle, *C. sordidus* is certainly not a recent introduction. As to the exact manner of its introduction, nothing definite is known.

To study the life history of the beetle and its habits in relation to Philippine conditions, with a view toward finding practical methods of reducing its ravages, the present work on *Cosmopolites sordidus* Germ. was undertaken. Most of the observations were made at the College of Agriculture, Los Baños.

MATERIALS AND METHODS

Observations on the character of injury, season of occurrence, methods of distribution, and habits of the insect were made in the banana and abaca plantations of the College. The plantations are all located on the College Farm, except an old abaca plantation, which is about 150 meters above sea level on Mount Makiling. Observations on host plants were made also in the fields. The life history was worked out in the insectary of the College. For this purpose, small banana suckers, jelly glasses, battery jars, kerosene cans, bamboo frames, cheese cloth and shellac in alcoholic solution were used.

FOOD PLANTS

According to published records, *C. sordidus* does not seem to have a great variety of host plants. The banana is its universal host. In the Philippines abaca furnishes the insect with an additional source of food supply.

There has been mention of the beetle having damaged sugar cane, but the writer could find no basis for this claim either from his own observations or in the literature.

CHARACTER OF INJURY

The beetle attacks banana plants of all varieties and at all stages of development. Injury to a very small sucker which had not yet come up above the surface of the ground was observed to have been done by a grub feeding on the bulb of the mother stool. (Plate II, figure 1.)

Two cases were observed where banana plants bearing fruits had been seriously affected. In these cases the fruits failed to develop to their normal size and fullness. The leaves were dry and the stools were so weak that a mere touch would push them over. The grubs were sometimes observed to dig out and tunnel the heart of the stem upwards to a height of about 25 centimeters. These two extreme types of attack are, however, rare. Most of the injury is done to suckers of the size best suited for transplanting, that is from 75 centimeters to 1.5 meters high.

In its early stage, the attack is not outwardly apparent. However, as the insect progresses, signs of attack become quite noticeable. The first outward indication that a sucker is attacked, is its loss of vigor. As the attack progresses, the pipe, or roll of unopened leaf, dies (Plate II, figure 2; Plate III, figure 1.) When this occurs, the attack is well advanced and the grub has eaten the growing point of the sucker. Later, the leaves dry up and the sucker falls over. Upon removing it and splitting it through, the bulb will be found to be riddled and tunneled (Plate III, figures 2 and 3.). This injury is characteristic of this weevil.

In older suckers the only sign of attack that is outwardly noticeable is the loss of vigor in the stools. The attack does not kill them, but they are so weakened that the flower clusters which they develop are abnormally small.

HABITS OF THE INSECT

The larvae can live on old suckers as well as on young ones and on decaying banana root stocks. In the fields, most of the adults were found in the decaying stools which had been cut and left in the plantation during harvest of the fruit. On December 28, 1920, as many as 19 adults were found on one decaying trunk.

It is not unusual to find the grubs on the root stock stumps left after harvest, for they breed on them freely. Out of some 20 stumps examined by the writer on December 27, 1920, only three did not show the presence of numerous grubs.

The adults (Plate I, figures 1 and 2) are inactive during the day, hiding under the decaying leaf sheaths on which they feed. In the latter part of the day up to early in the morning, they become active. Their period of greatest activity is from 6:00 o'clock in the afternoon to 6:00 o'clock in the morning. During that time they climb about on the plants or bore into the soil. In boring, the snout is first pushed into the soil, to loosen it, after which the first pair of legs is used to help put aside the soil particles.

The beetle seldom if ever takes to its wings, it goes about from place to place on foot. When it is disturbed, it stops a moment, playing dead, then when not further molested, moves on. After traveling one or two meters it stops to rest for a few minutes, then continues its travels. The writer has observed that this insect will cover over 15 meters in a single night on foot.

The female beetle lays her eggs singly in the outer leaf sheaths of the banana, not above 25 centimeters from the surface of the ground. It is not infrequent

that eggs are laid on the root stocks. The eggs are most often deposited on the stools just above the bulb, and on sheaths that are partly decayed.

The female finds a suitable place, usually the partly decayed leaf sheaths, for the deposition of her egg. Having located the place she rests for a moment, after which she makes a small pouch in the plant tissue for her egg. (Plate I, figures 3, 4 and 5.) The incision is made horizontally or slightly downward into the outer most leaf sheath, by means of her beak or snout. She then reverses her position and lays a single egg at the bottom of this pouch. The egg is so skillfully placed that it is often a very tedious job to locate it.

When the egg hatches, the minute grub, which is about two millimeters long, eats its way down in the sheath in which the egg was laid, continuing its travel, inwards and downwards, until it reaches the young fleshy part of the bulb where it remains for some time. Then it tunnels its way horizontally, then slightly upwards to the growing point of the sucker. In the heart of the sucker, it attains its full growth, measuring then about 15 millimeters in length and five millimeters in diameter. Here it travels up and down, tunneling the sucker to as high as five to ten centimeters above the surface of the ground. It is at this stage that the pipe of the sucker is killed. Finally the full grown larva tunnels its way downward and makes a roomy cell near the epidermis of the bulb, where it passes its transformation—the pupal stage. Upon emergence, the beetle pushes its way out of the bulb. It is several days after the emergence from the pupal case before the beetle comes out of the ground and seeks a hiding place among the decaying sheaths.

The insect follows the same process in its attack on the abaca plant.

EXTENT OF DAMAGE

The extent of injury in banana as well as in abaca seems to vary directly with the age of the plantation, and of course indirectly with the natural checks that hinder the progress of the insect.

In the old banana plantation of the College which was planted in the year 1915, although a very little material was obtainable, it is safe to say that not less than 25 per cent of the stools were attacked. In fact, out of 18 suckers dug from three average hills, seven of them showed signs of attack. Because the plantation is abandoned, and the plants are found only here and there, no extensive gathering of data was made.

The degree to which the infestation may occur on a comparatively new plantation which is well cultivated and taken care of, is shown in Table I. The plantation was established in the latter part of 1919, and since then clean cultivation has been practiced.

TABLE I.—*Showing extent of injury by Cosmopolites sordidus Germ. in a young banana plantation.*

Variety.	College number.	Relative variety height.	No. of hills examined.	Total No. of stools.	No. of stools attacked.	Per cent of stools attacked.
Pitogo	301	tall	15	32	0	0
Katali	5032	"	16	101	0	0
Sau Ilung chin	5204	"	16	70	0	0
Sabang Jolo	5362	"	17	62	0	0
Sabang Iloco	908	"	16	97	1	1.03
Saba	307	"	16	78	1	1.28
Padilat	5383	"	15	85	3	3.52
Ternate	2800	medium	14	38	0	0
Tombotok	5085	"	4	12	0	0
Litondan	5113	"	16	37	0	0
Latundan	5354	"	10	16	0	0
Boodal val	5408	"	16	117	0	0
Yau Vat Ching	5203	"	16	105	1	0.95
Daraya	5248	"	5	13	1	7.7
Cantong	5019	"	15	48	1	2.08
Tundan	5001	"	15	46	1	2.17
Bungulan	305	"	15	61	2	3.28
Pomme de la Martinique	52	medium to small	13	21	0	0
Musa manka	4980	medium to small	14	54	5	9.26
Lacatan	4979	medium to small	17	42	6a	14.28
Inarnibal	930	small	12	54	1	1.85
Kinamay	5000	"	5	26	1	3.84
Hawaiian Dwarf	803	"	12	34	2	5.88
Obob	5247	"	11	21	2	9.52
Veinte cohol	900	"	8	29	3	10.34
Puting cohol	2796	"	13	76	10	13.16

a One of these plants attacked was in fruit.

Each variety was planted in a separate row. In obtaining the percentage of attacked plants, the total number of stools on the whole row was counted, noting, at the same time, those which were suspected of being attacked. All the suspicious suckers were then dug up and the suckers which were actually attacked were counted. This number was then divided by the number of stools in the entire row and the result multiplied by 100.

An idea as to the extent to which the insect may attack the abaca plant may be gained by examining Table II.

TABLE II.—*Showing extent of injury by Cosmopolites sordidus Germ. to abaca.*

Variety.	College number.	Relative variety height.	No. of hills examined.	Total No. of stools.	No. of stools attacked.	Per cent of stools attacked.
Unknown	——	medium	9	92	16	17.39
Inosa	10305	"	8	70	0	0
Sugmod	4282	"	6	128	0	0
Bangulanon	4284	"	9	222	2	0.87
Sinamoro Puti	4279	"	6	145	2	1.38

The unknown variety is growing on Mount Makiling at an altitude of about 150 meters above sea level, and was growing there before the College was established in 1909. No care and cultivation have been given the plantation.

The other varieties are growing near the lower nursery of the College. They were planted in the latter part of 1918 in separate rows and since then the plantation has been well cultivated and taken care of.

METHODS OF DISTRIBUTION

The insect is undoubtedly distributed from one country to another and from plantation to plantation by the transportation of infested suckers and root stocks used for propagating purposes. The beetle seldom if ever flies, but it is able to cover on foot at least 15 meters each night. Besides by the introduction of infested suckers, the beetle may normally be spread in this way.

SEASON OF OCCURRENCE

In the Philippines, the insect is abundant and breeds freely at all seasons of the year. According to published records, this is also true in most other countries where it is found.

LONGEVITY OF THE ADULT BEETLES

These beetles are undoubtedly long lived. For the purpose of obtaining eggs of the insect, some beetles were enclosed in a battery jar with a banana sucker, on July 27, 1920. The beetles lived until November 4 of the same year, when, by mistake, the sucker with the beetles was thrown out. They lived for a total of 103 days in captivity. In the fields they probably live much longer.

The adults may be able to exist without food for considerable periods, but those experimented upon in the laboratory died within three days when they were confined without food.

LIFE HISTORY

Method of study.—At first, an effort to study the life history in the sucker was made. Banana suckers, about 25 centimeters high, were planted in kerosene cans—one plant to each can. Each can was then fitted with a bamboo frame, and a piece of cheese cloth was cut and sewed so as to fit the frame and the banana trunk. Openings, which could be closed with pins, were made in the cheese cloth, corresponding to the sides of the can. The cheese cloth was then pasted on the can with shellac. The portions of the cloth coming in contact with the frame and the banana stem were also wet with the solution. When dried, these portions were so leather-like in character that the beetles could not force their way through.

Beetles were captured and were introduced into the cages, and the cages examined daily. After some time, a difficulty in observation was met, in that the grubs could not be followed down into the bulbs of the plants. It was then decided to use the plants in the cages only for general observation and egg-laying purposes, and to carry on the molting observations in battery jars. Soon, however, it was found that the larvae could not be followed daily into the bulb without danger of crushing them. This was particularly true with the very small delicate grubs.

By making the molt observations between thin slices of the bulb in jelly glasses fitted with covers, all the previous troubles were eliminated. Two very thin slices of the bulb exactly fitted the bottom of the jelly glass when placed one over the other. A hole was made on the lower slice for the reception of the egg. The eggs were taken from the suckers in the cages, put in place, and the upper slice put on. The upper slice was used to cover the egg to protect it from exposure. The glass was then covered to protect the insect from outside injuries. After hatching, the grub fed on the inner slice. Since the slices were very thin it was impossible for the grub to get into them. By lifting the covering or upper slice, the larva was clearly exposed to view.

The slices were changed when more than one half of the inner slice had been eaten. Care was taken each time the slices were changed, so that their thickness never exceeded that of the larva. In this way, no difficulty was encountered in observing the different molts of the insect.

Table III gives records of the life history of *Cosmopolites sordidus* as studied in the laboratory.

TABLE III.—*Life History of Cosmopolites sordidus Germ. under laboratory condition.*

Egg No.	1	2	3	4	5	6
Date laid	3-1-21	3-1-21	4-1-21	5-1-21	5-1-21	8-1-21
Date hatched	8-1-21	9-1-21	11-1-21	9-1-21	11-1-21	13-1-21
First molt	15-1-21	15-1-21	19-1-21	17-1-21	18-1-21	18-1-21
Second molt	23-1-21	20-1-21	25-1-21	24-1-21	24-1-21	22-1-21
Third molt	30-1-21	28-1-21	30-1-21	31-1-21	30-1-21	30-1-21
Fourth molt	5-II-21	4-II-21	7-II-21	6-II-21	5-II-21	7-II-21
Fifth molt	11-II-21	11-II-21	12-II-21	12-II-21	13-II-21	17-II-21
Pupation	19-II-21	19-II-21	19-II-21	20-II-21	20-II-21	23-II-21
Emergence	27-II-21	28-II-21	1-III-21	26-II-21	28-II-21	4-II-21
Length of development	55 da.	56 da.	56 da.	52 da.	54 da.	55 da.

DESCRIPTIONS

For very excellent descriptions of this insect by Dr. W. D. Pierce the reader is referred to Moznette (13).

NATURAL ENEMIES

No natural enemies of the insect were observed to be actually parasitizing the weevil, although an adult Chalcid was found in one of the breeding cages when the insects were confined for life history studies in the insectary.

CONTROL AND REMEDIAL MEASURES

Various investigators on the subject have employed different methods of control, with varying degrees of success. Jepson made use of the natural enemies of the insect and reported a fair degree of success in their use. Knowles (5) reported CS_2 as most effective in killing the insect. He also made mention of

trapping the insect with pieces of sliced banana bulbs, and of the renewal of old plantations, as means of reducing the ravages of the insect. In Jamaica, they have found that soaking the infested suckers in water for 48 hours will drown the insect, and that the use of CS_2 and charring the suckers are impractical. The charring of the infested stools is practiced in Florida.

The methods experimented with in the present work were those which are inexpensive and could easily be adopted by the average Filipino farmer. Infested suckers were soaked for varying lengths of time in water and in water solutions of formaldehyde. The strengths of the formaldehyde solutions used were .1, 1, 1.5, and 2 per cent.

It was found that the formaldehyde has little if any effect on the killing of the insect. In water, the larvae and pupae died within 72 hours, but the beetles usually survived. Only in a few cases were the larvae found dead after 48 hours in the water. The beetles, although seemingly lifeless, usually recovered after they had been out of the water for some time. The writer observed that when the suckers were put in water, the adults usually crept to the parts of the suckers above the water. Practically the same results were obtained with each of the formaldehyde solutions used.

DISCUSSION OF RESULTS

Referring to Table I, it can be seen that the percentage of attack varies from 0—14.28. This small damage as compared with that of the older plantation is doubtless due to the care given the new plantation, and the difference in the age, since they are not very far apart. The table seems to show also that the medium-sized and the small-sized varieties were more severely attacked than were those of the larger size. This seems to point toward a possible practical method of reducing the ravages of the insect, by planting the more resistant larger varieties. This possibility, however, needs further experiment.

Although there are some varieties which show no signs of attack, it can not be said that they are immune, for every variety of banana is attacked, at least to some extent, by the weevil. The apparently immune are probably the more resistant varieties and are unmolested in the presence of the other varieties.

In abaca, we find a case similar to that cited above. It may be seen in Table II. While the older plantation had the advantage of being located up on the mountain, more isolated and thus less subject to infestation, the plants were more seriously attacked than in the newer plantation on the College farms which was much exposed to infestations from the nearby old banana plantation. As in the case of the banana, this may be due to the difference in their age and the care they received. A study of comparative susceptibilities of varieties of different sizes to the insect's attack can not be made here because all the plants at the College are abnormally small.

A very striking contrast may be observed in the banana and abaca plantations on the College Farm. The distance of each from the old seriously infested banana plantation is about the same. Both receive practically the same degree of cultivation and care. Yet, the abaca plantation is comparatively free from the weevil. Furthermore, a few banana plants growing near the abaca plantation were seriously damaged. It seems, then, that possibly abaca is less molested than banana. This, may probably be due to the presence in the abaca tissues,

both in the root stock and the trunk, of considerably heavier fiber materials than in banana. If this be true, then, one of the reasons which may account for the seriousness of infestation of abaca on the Makiling plantation may be the absence of the more palatable banana plants among them. It seems possible, that in localities where the interest of the people is more absorbed in abaca than in banana, the weevil attack on the abaca may be lessened by planting some banana plants among them which may serve as traps. However, this, again, is a mere possibility and needs further experimentation.

The length of the development of the beetle varies, in the laboratory, from 52 days to 56 days from the time the eggs are laid. The average is about 56 days. Since it is not until several days after emergence that the adult comes out of the ground to breed, there probably are not more than five generations of the insect in one year. The length of the larval stage under the same conditions varies from 42 to 45 days after the hatching of the egg.

In the submerging of the suckers in water, we find a very practical means, both in banana and in abaca, of checking the introduction of the weevil into a new plantation through infested stools. If banana and abaca suckers be submerged in water for at least 72 hours before they are transplanted, the suckers will be freed from the weevil. When the adults creep to the parts of the stools above the water, they will, in most cases, be readily seen, and can be collected and killed. The danger of missing them will be practically eliminated if the suckers are cut back to a point few centimeters above the root stock.

SUMMARY AND CONCLUSIONS

1. The banana weevil, *Cosmopolites sordidus* Germ., attacks banana and abaca plants in the Philippines.

2. All varieties of banana are, at least to some extent, attacked. The Bangulanon and Sinamoro Puti varieties of abaca and possibly others are also attacked.

3. It seems probable that the larger varieties of banana are more resistant to the insects attack than are those of smaller size. Further experimentation on the subject should be carried out.

4. The weevil seems to show preference to banana over abaca. This also needs further experimentation.

5. The normal spread of the insect is quite slow. It is distributed from place to place principally by the transportation of infested suckers and root stocks.

6. Infested stools can be freed from the weevil by submerging them in water for, at least, 72 hours.

7. Formaldehyde in water solutions has no better effect than water in drowning the weevil.

RECOMMENDATIONS

The stools cut during harvest should not be left around in the fields. They will harbor the beetles and act as breeding places for them.

Plantations should always be kept in a proper condition of cultivation. Very old plantations should be cut down, and the land plowed. Crop rotation should be practiced.

Efforts should be made to select only those suckers and roots stocks that are not attacked by the weevil, for propagating purposes. Care should be taken that none of the weevils go with them to the new banana plantation. These propagating materials should be submerged in water at the place where they are dug, for at least 72 hours before they are shipped, to be sure that no adults remain.

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ILLUSTRATIONS

Plate I

Fig. 1. Adult *C. sordidus* Germ., female (X4).
2. Adult *C. sordidus* Germ., males (X4).
3. An egg, side view (X16).
4. An egg, dorsal view (X16).
5. An egg in *situ* (X12).

Plate II

Fig. 1. A banana root stock badly attacked by the weevil. The small sucker marked (X) was attacked.
2. Banana suckers attacked by the banana weevil. Note the characteristic absence of the "pipe".

Plate III

Fig. 1. Top of an abaca sucker showing the dead "pipe" still in position.
2. The sucker shown in Plate III, fig. 2, halved, to show the tunnels made by the grub of the weevil.
3. The other half of the same root stock.

1

3

4

2

5

PLATE I.

PLATE II.

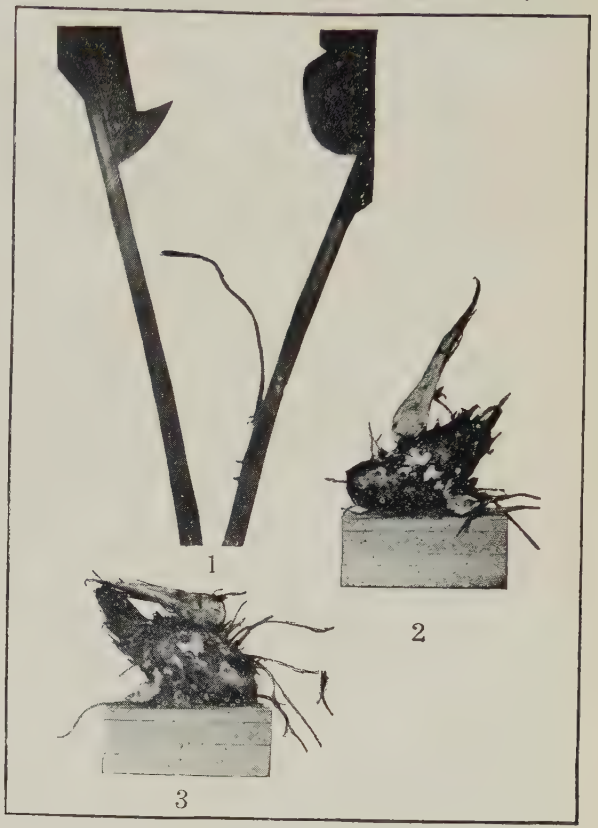


PLATE III.

EFFECT OF TIME OF PLANTING ON GROWTH AND YIELD OF A LOWLAND RICE IN PEÑARANDA, NUEVA ECIJA AND ON THE COLLEGE FARM [1]

By Ambrosio P. Abesamis

The experiments reported in this paper deal with the effect of time of planting on growth and yield of a lowland rice. Rice like any other crop has its own seasonal growth and adaptability to certain climatic conditions. As it is distinctly a rainy season crop, it requires a certain amount of water either in the form of rain or by irrigation for its successful growth and development. Rain is a vital factor in giving the proper humidity of the atmosphere that the plant requires. Besides water, many other environmental factors, such as food, or fertility of soil, and temperature are necessary for its growth, but these may be considered as minor necessities. In order to obtain such requirements, rice must be planted at the right time.

There has been very little work done on this subject of effect of time of planting rice. A study of the relation of climatic conditions to the vegetative growth and seed production of rice was made on the College Farm by Peralta (1). He planted every four weeks during a period of one year from April 1916, to April 1917. He found that Inintiw rice, when transplanted during the months of May, June, and July, gave good returns, both in straw and grain.

According to Smith (2), the Deputy Director of Agriculture in Bengal, whose autumn rice or Aman Paddy experiments were carried on from the year 1891 to 1906, "the normal season for the paddy crop requires a rainfall of 10.17" (258.04 mm.) in June, 12.32" (313.14 mm.) in July, 11.49" (292.04 mm.) in August and 8.59" (218.33 mm.) in September. It is exceedingly important that the early rainfall should be sufficient to allow transplanting by the middle of July, otherwise the return of the crop is very appreciably diminished. The date of transplanting and the amount of rainfall in paddy cultivation are very important factors."

The objects of the experiments reported in this paper were to determine (a) which part of the rainy season in Peñaranda, Nueva Ecija, Philippine Islands, is well adapted to the cultivation of Inintiw variety of rice, when the water supply of the soil depends upon rain only, and (b) which part of the rainy season on the College Farm, Los Baños, Laguna, Philippine Islands, is well adapted to the cultivation of Inintiw variety of rice, when the water content of the soil is supplied by rain and by irrigation.

The practical importance of this piece of work is that it may serve as a guide to rice growers in fixing the proper time of planting, so as to produce better crops.

The experiments were carried out on the College Farm, Los Baños, Laguna, Philippine Islands, and in Peñaranda, Nueva Ecija, Philippine Islands, in the year 1920.

[1] Thesis presented for graduation from the College of Agriculture, No. 136; Experiment Station contribution, No. 78.

MATERIALS AND METHODS

For these experiments Inintiw rice seed taken from the 1919-20 harvest of Isidoro Collado was used. The seed was harvested from the ungraded seed or check parents seed. It bears the College number 3052 F5. This variety can be grown under both upland and lowland conditions. It matures early and is said to be resistant to drought.

Peralta (1) describes this variety of rice as follows: "It is 141.3 cm. high with 3.2 bearing culms with 5.7 nodes; the leaf is catchy, 62 cm. long and 1.15 cm. wide. The panicle is closed with few grains. The grain is catchy, light orange-yellow, 7.8 cm. long and 3.23 cm." (7.8 cm. long and 3.23 cm. wide are wrong denominations. These should be 7.8 mm. long and 3.23 mm. wide.)

Two sets of experiments, called Set I and Set II, with almost similar experimental methods were carried out. Set I was carried out at Peñaranda, Nueva Ecija and Set II on the College Farm. These two places have different types of climatic conditions. According to the classification made by the Director of Weather Bureau, Rev. José Algue (3), Peñaranda falls under the second type, while the College of Agriculture falls under the third type.

SECOND TYPE

The characteristics of the climatic conditions of the second type are:

I. There is distinct wet and dry season in this type, the dry lasting generally from the end of November to March.

II. The percentage of rainfall during the months from June to October, popularly called the rainy season, is at least 76 per cent of the total precipitation of the year, while the rainfall from November to February never exceeds 12 per cent of the total average. April and May are apt to have more precipitation than the dry months owing to electric storms, and occasionally, especially in May, to cyclones.

III. Amount of clouds follows precipitation or rather shows the average precipitation. Clearest months from January to April, cloudiest months September, August and July.

IV. The annual percentage of humidity is not very high owing to the influence and duration of the dry season. Annual percentage is not more than 80 per cent.

V. The temperature is either high or intermediate, seldom or never mild.

SECOND TYPE
RÉSUME

Rainfall	Heaviest	June, July, August, September, October.
	Regular	November, December, April, May.
	Mildest	January, February, March.
	Total yearly, 2,454 mm.	
	Very distinct wet and dry seasons.	
Humidity	Large range, 70-86.	
Temperature	Around 27° centigrade.	

THIRD TYPE

The characteristics of the climatic conditions of the third type are:

I. There is a short period of dry season in the regions of this type, lasting one or two months generally between January and April, according to the more or less prevalence of wet easterly current over the place, controlled mostly by the distance from the Pacific. We may consider as dry a month with less than 50 mm. rainfall. Average total rainfall for the year is less than 2,000 mm.

II. The percentage of rainfall from November to February is less than 20 per cent of the total precipitation for the year. Percentage for the months of June to October very seldom exceeds 60 per cent.

III. Cloudiness follows the amount of rain, which seems to be uniform during the year except for a short period of less rain; so that the clearest month is, as an average, the least rainy month.

IV. The relative humidity is lower than the regions of this type south of Luzon. However, the average percentage of each month oscillates in the same manner as the rain.

V. The temperature in this type is generally intermediate on the seashores and high inland where, of course, the altitude above the sea level is below 80 meters.

THIRD TYPE
RÉSUME

Rainfall	Heaviest	July, August, September, October, November.
	Regular	May, June, December, January.
	Mildest	February, March, April.
	Total yearly, 1,856 mm.	
	Short period of dry season, January-April.	
Humidity	Very small range, 74-69.	
Temperature	Around 26° centigrade.	

In Set I, or Nueva Ecija cultures, the seed bed method employed is commonly called *punlaan* (Tagalog). Seed was sown every ten days from May 31 to June 30. Seedlings were transplanted when forty-five days old.

The following criteria were observed in Set I.

1. Height of seedlings when transplanted.
2. Rate of recovery of seedlings.
3. Date of flowering.
4. Total height of 25 average plants from each culture at harvest time.
5. External appearance of plants during growing stage and at harvest.
6. Susceptibility of plants to insects pests, and other enemies.
7. Weight of straw and grain.
8. Weight of all seeds.
9. Weight of good seed.
10. Weight of straw.
11. Weather records.

In Set II, or College of Agriculture cultures, the drill method of seed bed was employed, instead of *punlaan*. Seeds were sown every fifteen days from May 31 to August 13. Seedlings were transplanted when forty-eight days old.[2]

The criteria used in Set II were the same as in Set I with the addition of the following:

1. Weekly measurement of growth of 25 plants from each paddy culture after transplanting.
2. The yield of straw and grain from these 25 measured plants.

EXPERIMENTS AND RESULTS

SET I, OR NUEVA ECIJA CULTURES

Seed bed.—To obtain water to saturate the soil of the seed beds, they were placed near a well. The soil is clay loam with a thin layer of alluvial soil on the surface. It was previously planted with corn.

The soil was plowed and harrowed both ways until it was well pulverized. A plot 8 by 8 meters was laid out. This was then divided into four equal parts by narrow dikes. They were numbered, Seed bed 1, Seed bed 2, Seed bed 3, and Seed bed 4.

[2] The seedlings of the first seed bed sown on May 31 were discarded because of the lack of water supply in the irrigation system of the College and the late rainfall, which made impossible the preparation of the rice paddy. The seedlings sown on June 14 were planted on August 2 in a paddy prepared dry. On account of the failure of rainfall from August 2 to August 14 inclusive, the seedlings perished for want of moisture.

On the day of sowing each seed bed was saturated with water from the well. The soil was harrowed with the implement *suyod* (Tagalog) until puddled, that is, until the soil was muddy. The beds were levelled at the same time they were harrowed.

Sowings were made on May 31 on Seed bed 1; on June 10, on Seed bed 2; on June 21, on Seed bed 3; and on July 1, on Seed bed 4.

The seed which had been soaked in water for twenty hours and germinated was scattered broadcast on the mud where it settled. The advantages claimed for this method are maximum germination and rapid growth, while the disadvantages are uneven sowing due to water and difficulty in separating the seedlings.

Paddies.—Four paddies each 20 by 20 meters were used for these cultures. Each was given the number corresponding to the seed bed number. The paddies were uniformly level and were located side by side. They were considered by the writer to be uniform in fertility and in water-holding capacity. These paddies had been previously planted with rice for four successive years, from 1916 to 1918. The soil is brownish clay and may be classified as an average soil suitable for rice cultivation in Nueva Ecija.

When perfectly saturated with water, the paddies were plowed once on June 2, 1920. The paddies after plowing were saturated or under water most of the time. This condition favors the decaying of grass or weeds which were plowed under.

Each paddy was harrowed a day before transplanting. Harrowing was done crosswise so as to puddle the soil and make the surface uniformly level. This preparation was made while the land was under water. This insures the destruction of weeds and wild grass that start growth when left in the field.

The first transplanting was commenced on July 15, the second on July 26, the third on August 5, and the fourth on August 14.

The seedlings were carefully pulled up and about 15 centimeters of the top portions were cut off. The seedlings were planted in hills about 25 centimeters apart both ways, with two seedlings in a hill. The distance between hills was not actually measured, only estimated by the planters as they worked.

Measurement.—Before the seedlings in each seed bed were transplanted, the heights of twenty-five plants were measured. The plants measured were not selected but were picked according to their location in the bed, so they represent a fair average of all of the seedlings.

At harvest the height of twenty-five plants in each paddy culture was measured. These plants were selected from five portions of each paddy as follows: five plants from the center, and five from each of the four corners of the paddy. At the same time the plants were measured, the number of bearing culms of each hill was recorded.

Harvesting.—Harvesting was done when all the grain was ripe. The panicles were cut from the top nodes of the culms and the straw just above the surface of the ground. The straw and panicles were dried for about seven days. At this time they were air-dry and had a constant weight. The panicles and straw were weighed separately. After weighing, the grains were removed and weighed. These grains were composed of both good and undeveloped seeds. To remove the undeveloped seeds, the grains were winnowed in a shallow basket. The good grains were then weighed.

TABLE I.—*Observations and yield data for rice grown in each paddy culture in Set I.*

Culture Number.	1	2	3	4
1. Date sown	5–31–20	6–10–20	6–21–20	7– 1–20
2. Date transplanted	7–15–20	7–26–20	8– 6–20	8–14–20
3. Average height of seedlings just before transplanting, in cm	38.10	39.22	37.65	39.54
4. Age of seedlings when transplanted, in days	45	46	45	44
5. Date of flowering	9– 4–20	9–14–20	2–23–20	10– 2–20
6. Average height of plants at harvest, in cm	107.49	102.36	75.64	60.78
7. Average number of bearing culms	6.80	6.08	4.68	3.16
8. Date harvested	10–29–20	11– 8–20	11–18–20	11–27–20
9. Age from sowing to harvest, in days	151	151	151	149
10. Total air-dry weight of good grain, in kg	33.71	32.81	9.24	4.32
11. Total air-dry weight of straw, in kg	80.46	80.02	29.26	13.16
12. Yield in cavans (grain unhulled) in each culture per hectare	19.60	19.08	5.37	2.51
13. Area planted per culture, in sq. m	400	400	400	400

Weather records.—The daily rainfall and temperature from the time of sowing in seed bed till harvest were obtained from a weather observatory station at San Isidro, Nueva Ecija. San Isidro is about 15 kilometers from Peñaranda where these experiments were performed. The two places have approximately the same altitude, though Peñaranda may be slightly higher than San Isidro. Being so near together the rainfall may be considered about the same in these two places. The calculated weekly rainfall and temperature are shown in Table II.

TABLE II.—*Weekly rainfall; monthly rainfall; and weekly mean temperature from sowing to harvesting in Set I.*

Date.	Weekly rainfall.	Monthly rainfall.	Temperature.
	mm.	*mm.*	*°C.*
May 30 to June 5, 1920	44.40		28.04
June 12, 1920	34.80		28.08
June 19, 1920	2.60		29.02
June 26, 1920	20.10	164.00	29.19
July 3, 1920	70.00		27.05
July 10, 1920	180.00		28.21
July 17, 1920	63.40		26.63
July 24, 1920	328.90		26.10
July 31, 1920	73.60	653.80	26.73
August 7, 1920	30.20		28.35
August 14, 1920	107.00		28.65
August 21, 1920	52.10		28.26
August 28, 1920	241.80	478.50	27.59
September 4, 1920	60.60		27.51
September 11, 1920	13.70		27.26
September 18, 1920	17.00		28.73
September 25, 1920	111.90	207.50	26.31
October 2, 1920	64.40		27.31
October 9, 1920	20.60		27.34
October 16, 1920	85.60		27.46
October 23, 1920	46.90		27.35
October 30, 1920	1.10	165.90	26.17
November 6, 1920	45.40		26.10
November 13, 1920	12.00		28.89
November 20, 1920	9.20		25.82
November 27, 1920	0	71.30	26.64

SET II, OR LOS BAÑOS CULTURES

Seed bed.—A place near the irrigation canal of the College was selected for seed beds. The soil is clay loam and easily worked. It was previously planted with cassava.

The soil was forked and pulverized. Four beds 1 by 6 meters were laid out. Each bed was raised about 12 centimeters. The surface was raked and leveled. The seed beds were numbered as Seed bed 1, Seed bed 2, Seed bed 3, and Seed bed 4.

Sowing was done on June 29, on Seed bed 1; on July 10, on Seed bed 2; on July 29, on Seed bed 3; and on August 13, on Seed bed 4.

With a sharpened stick, holes were made in rows 10 centimeters apart both ways, and four centimeters in depth and in diameter. From five to fifteen or more seeds were dropped in a hole and covered with a thin layer of soil. Watering was done after sowing whenever rain failed to fall for several days.

Paddies.—Four paddies each 20 by 24 meters were used for these cultures. Each was given a number corresponding to the seed bed. The paddies were located side by side. They had been previously planted with rice. The soil is clay loam with porous subsoil. This kind of soil is not suited for lowland rice culture, because it is porous and the water does not stay long on the surface.

Plowing was done while the soil was fairly wet. After plowing, the water from the irrigation canal was turned into the paddies to saturate the soil thoroughly. The method of harrowing was the same as used in Set I.

The first transplanting was commenced on August 16; the second on August 31; the third on September 15; and the fourth on September 30. The method was the same as that followed in Set I.

Measurement.—The height of twenty-five seedlings in each bed was measured before transplanting, as was done in Set I.

After transplanting, weekly measurements of the growth in height were made. Twenty-five plants were measured in each paddy. These plants were selected as follows: five plants from the center and five plants from each of the four corners of each paddy. They, therefore, represent a fair average of the plants. Beside each of these twenty-five plants a small stake was driven which served as a base mark for height measurements.

The twenty-five measured plants in each paddy were harvested separately and photographs were taken to show the relative heights, productivity, and stooling of the plants in each plot. These are shown in Plate I.

These plants were dried for seven days at which time they had a constant weight. The panicles of these plants were cut from the top nodes of the culms and the roots stocks were removed by cutting the stalks at the very base. The panicles and straw were weighed separately. After this weighing, the grain was cleaned of undeveloped seed and other foreign materials; then this good grain was weighed.

General harvest.—The method of harvesting was the same as followed in Set I.

TABLE III.—*Observations and yield data for rice grown in each culture in Set II.*

	Culture number	1	2	3	4
1.	Date sown	6–29–20	7–29–20	7–29–20	8–13–20
2.	Date transplanted	8–16–20	8–31–20	9–15–20	9–30–20
3.	Average height of seedlings just before transplanting, in cm	30.80	33.96	38.07	36.88
4.	Age of seedlings when transplanted, in days	48	48	48	48
5.	Date of flowering	10– 2–20	10–17–20	10–30–20	11–11–20
6.	Average height of plants at harvest, in cm.	110.87	72.24	65.44	83.91
7.	Average number of bearing culms	6.88	3.84	3.80	6.80
8.	Date harvested [a]	11–20–20	12– 3–20	12–16–20	12–27–20
9.	Age from sowing to harvest, in days	144	142	140	135
10.	Total air-dry weight of good grain, in kg.	71.30	12.10	5.60	20.00
11.	Total air-dry weight of straw, in kg.	147.70	40.70	29.60	72.00
	Measured Plants				
12.	Number of plants measured	25	25	25	25
13.	Total air-dry weight of good grain, in gm.	173.10	47.27	45.66	84.91
14.	Total air-dry weight of straw, in gm.	348.68	94.50	76.91	169.09
15.	Mean yield of good grain per plant, in gm.	6.92	1.89	1.83	3.40
16.	Mean yield of straw per plant, in gm.	13.95	3.78	3.08	6.76
	General data for entire culture [b]				
17.	Total air-dry-weight of grain, in kg.	71.47	12.15	5.65	20.09
18.	Total air-dry-weight of straw, in kg.	148.05	40.75	29.68	72.17
19.	Yield in cavans (grain unhulled) in each culture per hectare	34.63	5.89	2.74	9.73
20.	Area planted per culture, in sq. m.	480.00	480.00	480.00	480.00

[a] The twenty-five plants measured were not included in this harvest.
[b] The twenty-five plants measured were included here.

TABLE IV.—*Weekly growth rate of rice in paddy culture in Set II.*

	Culture number	1	2	3	4
0.	Date transplanted	8–16–20	8–31–20	9–15–20	9–30–20
		cm. (7) [a]	*cm.* (6) [a]	*cm.* (5) [a]	*cm.* (4) [a]
1.	First week (1st monday)	4.64	2.92	1.70	3.60
2.	Second week	7.71	2.00	2.92	3.38
3.	Third week	3.60	3.98	3.37	6.16
4.	Fourth week	13.32	8.47	5.42	5.28
5.	Fifth week	9.33	7.15	4.62	8.97
6.	Sixth week	11.46	5.19	4.65	7.79
7.	Seventh week	10.35	4.27	8.55	14.24
8.	Eighth week	14.91	4.90	7.48	7.94
9.	Ninth week	18.37	15.03	10.30	10.50
10.	Tenth week	7.95	4.54	2.74	6.73
11.	Eleventh week	0	2.35	1.58	.31
12.	Twelfth week	0	0	0	0
	TOTAL	101.64	58.80	53.33	71.66
	AVERAGE	8.47	4.90	4.34	5.97

[a] The figures in parenthesis are the number of days from the first measurement (date transplanted) to the second measurement.

Weather Records.—The daily rainfall and temperature from the time of sowing in seed beds till harvest were obtained from the weather records observed

by R. P. Estioko at the College Station. The field used in this experiment was about 100 meters from the place where the rain-gauge is located and about 300 meters from the thermometer. The calculated weekly rainfall and temperature are shown in Table V.

TABLE V.—*Weekly rainfall; monthly rainfall; and weekly mean temperature from sowing to harvest, in Set II.*

Date.	Weekly rainfall.	Monthly rainfall.	Temperature.
	mm.	*mm.*	*°C.*
June 28 to July 5, 1920	36.6		25.9
July 12, 1920	74.6		25.9
July 19, 1920	90.8		26.5
July 26, 1920	79.3	306.20	27.4
August 2, 1920	31.2		26.6
August 9, 1920	0		27.8
August 16, 1920	1.4		27.7
August 23, 1920	121.6		26.6
August 30, 1920	87.6	241.70	26.2
September 6, 1920	136.2		26.1
September 13, 1920	2.8		27.0
September 20, 1920	35.5		26.5
September 27, 1920	166.4	334.80	24.8
October 4, 1920	46.9		26.9
October 11, 1920	73.8		26.0
October 18, 1920	38.5		25.7
October 25, 1920	25.1	170.20	25.2
November 1, 1920	.8		25.1
November 8, 1920	78.1		25.5
November 15, 1920	117.9		25.1
November 22, 1920	71.0		24.8
November 29, 1920	36.6	315.10	25.2
December 6, 1920	68.5		24.6
December 13, 1920	44.1		25.5
December 20, 1920	83.8		24.8
December 27, 1920	10.9	198.70	22.3

PEST AND ENEMIES

Pests.—In Set I, or Nueva Ecija cultures, practically no insects pests were noticed. In Set II, or Los Baños cultures, rice bugs (*Leptocorisa acuta*) were present periodically in all of the four cultures. Not much damage was done by them.

Birds.—(*Mayas*), *Munia jagori*, Martins damaged the first two cultures of Set I and the last two cultures of Set II. The greatest damage was done at the milk stage of the grain. One should not plant rice on a small scale in any isolated region where these birds are numerous.

Rats.—In the first two cultures of Set I, rats committed some depredation. Some of the stalks were cut near the base and some were lodged on the ground.

DISCUSSION OF RESULTS

RELATION OF CLIMATIC CONDITIONS TO YIELDS OF SET I, OR NUEVA ECIJA CULTURES

As shown in Table I, though sowing was done at intervals around ten days, the average height of the seedlings in each culture did not vary widely. The range was from 37.65 to 39.54 centimeters. The ages of the seedlings before being transplanted were also fairly uniform, ranging from 44 to 46 days. The

seedlings, therefore, in these four cultures had apparently uniform development before they were transplanted. Having this uniformity in the seedlings and uniformity in the soil of the four paddies used, the differences, therefore, in the outcome of each culture may be accounted for entirely by the effect of environmental factors which we call climatic conditions. These differences will be noticed in the following criteria: (1) Average height of the plants; (2) Average number of bearing culms; (3) Total air-dry weight of straw; (4) Yield in grain calculated per hectare in cavans (grain unhulled). These are shown in Table VI.

TABLE VI.—*Dates transplanted; age at maturity; yield data and amount of rainfall from transplanting to harvest of each of the four cultures at Peñaranda, Nueva Ecija.*

Culture number.	Date transplanted.	Age from transplanting to harvest.	Yield data				Amount of rainfall from transplanting to harvest.
			Average height of plants.	Average number of bearing culms.	Yield in cavans (grain unhulled) per Ha.	Total air-dry weight of straw per Ha.	
		days	*cm.*		*cavans*	*kg.*	*mm.*
1	7–15–20	151	107.49	6.80	19.60	2011.50	1261.00
2	7–26–20	151	102.36	6.08	19.08	2000.50	976.10
3	8– 5–20	151	73.64	4.68	5.37	731.50	890.50
4	8–14–20	149	60.87	3.16	2.51	329.00	783.50

An examination of Table VI reveals the fact that Cultures 1 and 2 which were transplanted on July 15 and 26, respectively, gave high yields in all the four criteria here used. These two cultures received a greater amount of rainfall from transplanting to harvest than the poor Cultures 3 and 4. This is shown in last column of table.

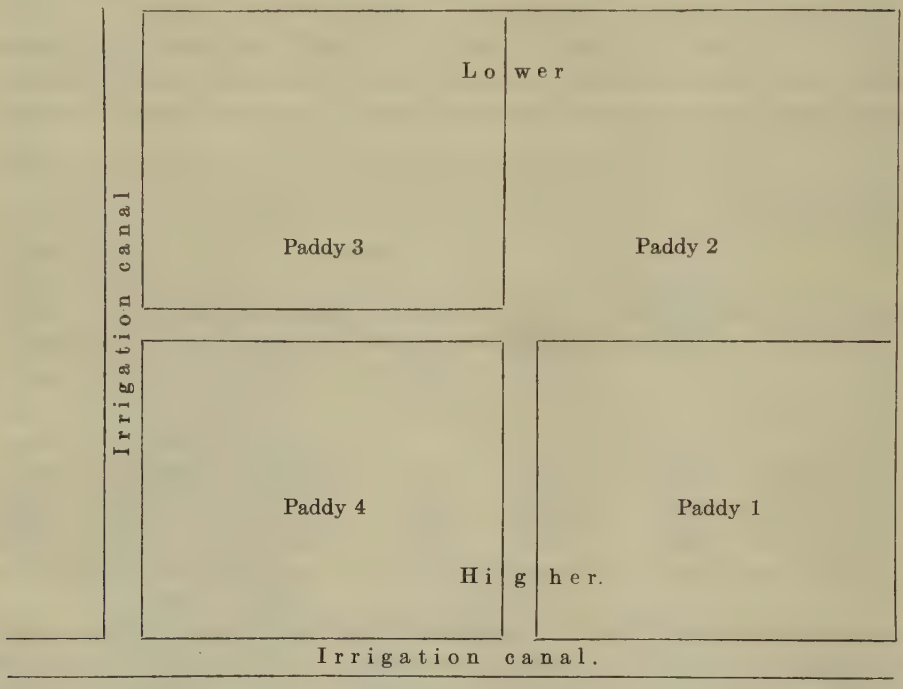
Cultures 1 and 2 were transplanted at the times when the amount of rainfall was fairly large, and the temperature low, while Cultures 3 and 4 were transplanted at times when the average rainfall was fairly low and the temperature high. It was observed that the soil of these poor cultures became partly dry after transplanting, which resulted in a stunted growth of the newly planted seedlings.

The dates of flowering with the exception of Culture 2 were at times when the amount of rainfall was medium in amount. Culture 2 at flowering time received but small amount of rain. The soil, however, was saturated with water and so the effect was not great. The very poor yields therefore of Cultures 3 and 4 were due to the dry condition of the soil and to the small amount of rainfall that they received soon after transplanting.

As shown in Table III, the seedlings in each culture had the same age when they were transplanted, yet the average heights were of a wider range than in Set I. The range was from 30.8 to 38.07 centimeters. Culture 3 had the highest average growth of the seedlings while Culture 1 had the lowest. But though Culture 3 had better seedlings as indicated by greater height, yet the yield was very poor, while Culture 1 which had the poorest seedlings gave the best yield. This shows that there were more important factors than the vigor of the seedlings that favored the growth and development of Culture 1.

RELATION OF CLIMATIC CONDITIONS TO YIELDS OF SET II, OR LOS BAÑOS CULTURES

The diagram shows the plan of the location of the paddies.



The differences in the yields of these four cultures of Set II were noticed in the four criteria mentioned in discussion of Set I. In addition to these four criteria, the rate of growth was added, for weekly measurements were made in this set of experiments. These are shown in Table VII.

TABLE VII.—*Dates transplanted; age at maturity; yield data under each of the five criteria; and amount of rainfall from transplanting to harvest.*

Culture number.	Date transplanted.	Age from transplanting to harvest.	Yield data.					Amount of rainfall from transplanting to harvest.
			Av. weekly growth.	Av. height of plants.	Av. number of bearing culms.	Yield in cavans (grain unhulled), per Ha.	Total air-dry wt. of straw per Ha.	
		days	*cm.*	*cm.*		*cavans*	*kg.*	*mm.*
1	8–16–20	144	8.47	110.87	6.88	34.63	3084.38	1012.30
2	8–31–20	142	4.90	72.24	3.84	5.89	848.96	903.00
3	9–15–20	140	4.54	65.44	3.80	2.74	618.33	885.70
4	9–30–20	135	5.94	83.91	6.80	9.73	1503.54	719.60

An examination of Table VII reveals the fact that Culture 1 which was transplanted on August 16 gave the highest yield in all the five criteria here used. This culture received the greatest amount of rainfall from transplanting to harvest as shown in last column of table.

This culture was transplanted at the time when the amount of rainfall was very low. This condition, however, did not affect unfavorably the newly planted seedlings as there was enough water supply from the irrigation system.

The very poor Cultures 2 and 3 as shown in Table VII were transplanted on August 31, and September 15 respectively. The amount of rainfall from transplanting to harvest was very low in comparison with Culture 1. These very poor cultures flowered at the time when the amount of rainfall was fairly low.

Culture 4 gave a higher yield than either of the very poor Cultures 2 and 3, though the amount of rainfall received during the growing period was the smallest, as shown in Table VII. The reason for this is not fully understood. It might have been due to the greater amount of water received from the irrigation system, or to slightly better soil than that of Cultures 2 and 3, since it was immediately adjoining Culture 1 which gave the highest yield.

Comparing the yields of the best cultures in these two sets of experiments, it will be noticed in Tables VI and VII that Culture 1 of Set II, or Los Baños culture gave the highest yield in all the criteria here used, though the amount of rainfall was greater in Culture 1 of Set I. This is due to the fact that the seed used in Set I, or Nueva Ecija cultures was native of Los Baños. The plants grown from these seeds were subjected to different soil and climatic conditions. A similar result was obtained by Macasaet, (4) in his work on Philippine corn culture with special reference to source of seed and distancing. He concluded that transporting seed corn from a locality to one at some distance seems to decrease production.

As to the age at maturity it will be seen in Table VI and VII that Nueva Ecija cultures in general had a greater age of maturity than Los Baños cultures. This is due to the greater amount of rainfall that Nueva Ecija cultures received. The same relationship between rainfall and length of growing period is also noticeable in comparing the cultures within each set and especially so for those of Set II, the Los Baños cultures. The cultures receiving the greater amount of rainfall matured later than the cultures receiving small amount of rainfall. This shows then that the greater amount of rainfall induced late maturity while insufficient amount favored early maturity.

SUMMARY OF CONCLUSIONS

With the methods here employed and the climatic conditions met during the progress of this work, it appears that the time of transplanting and the amount of rainfall are determining factors in rice yield.

With the exception of the last Culture 4 of Set II, it can be stated in general that the yields were directly related with the amount of rainfall from transplanting to harvest; high yields were correlated with large amount of rainfall; and low yields with small amount of rainfall.

Considering both straw and grain yields of Set I, the best cultures which were transplanted on July 15 and 26 respectively, and which received the great amount of rainfall ranging from 976.10 to 1261.00 millimeters, gave an average yield about six times the average yield of the poor cultures which received the smaller amount of rainfall.

The same thing was true in the case of Set II. The best culture which was transplanted on August 16 and received a large amount of rainfall gave a yield about 5.6 times the average yield of the last three poor cultures which received smaller amount of rainfall.

It appears, also, that the age at maturity was related to the amount of rainfall; later maturity was correlated with greater amount of rainfall received, and early maturity with lesser amount of rainfall.

ACKNOWLEDGEMENT

The writer is greatly indebted to Dr. Forman T. McLean, of the Department of Plant Physiology, under whom this work was undertaken, for his advice and suggestions, and to Dr. R. B. Espino for his help during the absence of Doctor McLean.

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SOLANACEOUS WILT IN THE PHILIPPINE ISLANDS[1]

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THREE PLATES

The most serious disease of tomato, egg-plant, and tobacco in the Philippine Islands is the widely distributed solanaceous wilt caused by *Bact. solanacearum* E. F. Smith. The disease is very noticeable in tobacco fields and nearly every year reduces the crop from ten to twenty per cent in those districts where the soil is heavily infested with the wilt organism. The tomato crop is likewise reduced by this disease. In certain portions of the College of Agriculture Experiment Station during the dry season of 1921 the tomato plants were entirely destroyed before any fruit was produced. Egg-plant in the same garden was so seriously parasitized that very few plants produced fruit and those which matured to that stage fruited lightly.

Because of the prevalence of solanaceous wilt and because the crops it injures are so important in the Philippine Islands, it was believed that investigations into the causal organism, hosts parasitized, and control or possible means of reduction of loss, would be invaluable. This paper presents the progress which has been made in the understanding of the above mentioned points.

REVIEW OF LITERATURE

Wilt of solanaceous plants has been known definitely since 1896 when E. F. Smith (1) carried on experiments with pure cultures of the causal organism and made inoculations which proved its identity. He named it *Bacillus solanacearum*. Later, he changed the genus to *Bacterium* to comply with his revision of Migula's classification.

In 1903 McKenney according to Smith (2) working at the South Carolina Experiment Station observed and described a wilt disease of tobacco which appeared to be caused by bacteria. Later on in that year Stevens and Sackett (3) made further studies on the disease and named it "Granville tobacco wilt," the name being taken from Granville county, N. C.

Smith (2) discusses at length and gives detailed reports of the disease including cultural studies and cross inoculations of the organism into both solanaceous and non-solanaceous hosts.

According to Smith (2) Honing has found *Bact. solanacearum* E. F. S. parasitic on *Pouzolzia* sp., *Physalis angulata, Indigophora erecta, Arachis hypogaea Mucuna* sp., *Acalypha boehmeroides, Ageratum conyzoides, Spilanthes acmella, Pluchea indica, Blumea balsamifera, Synedrella nodiflora,* and *Tectona grandis* besides several varieties of *Nicotiana, Capsicum annuum,* and *Sesamum indicum.*

Stanford and Wolf (4) inoculated successfully the following hosts: *Stizolobium niveum, Tropaoelum lobbianum, T. perigrinum, Croton glandulosus* var. *septentrionalis, Impatiens balsamina, Verbena ericoides, Lycopersicum cerasiforme, Salpiglossis sinuata,* and *Martynia proboscidea.*

[1] Experiment Station contribution No. 79.

Bryan (5) while working on a wilt of nasturtium found that it was caused by no other organism than *Bact. solanacearum* E. F. S. She consistently caused typical solanaceous wilt by artificial inoculation.

Smith and Godfrey (6) found that a common wilt of the castor bean in southern United States was caused by the same organism and initiated typical solanaceous wilt in solanaceous as well as some non-solanaceous hosts. A stunting of the castor bean plant is very common and is traced by Smith and Godfrey, to *Bact. solanacearum.*

Smith (2) states that the following plants are parasitized by the organism when isolated from any of the common solanaceous hosts: *Solanum nigrum, Datura stramomium,* cucumber fruits, *Physalis classifolia, P. philadelphia,* feeble in petunia.

Garner, Wolf, and Moss (7) find that it is not safe to use peanut in a rotation for control, for it will not aid in driving out the wilt. They state further that sweet potato is not so good as other crops to grow in the rotation as it will not starve out the solanaceous wilt organism.

It is interesting to note that when carrying on many inoculations in 1902-1905, Smith was unable to cause the wilting of *Ricinus communis* with any of his strains of the solanaceous wilt organism.

Smith states further that the vascular elements are frequently clogged with bacterial cells, that phloem cells are also invaded and that frequently closed cavities are formed in the parenchymatous tissues. In tomatoes there is a premature development of adventitious roots, and frequently there is a slight enlargement of the stem at the point of inoculation.

Smith (6) states as follows concerning the morphology of the organism: "Short rod, often termo-like, motile, flagella polar; organism in plant often easily mistaken for a coccus."

He states further that the organism produces a brownish pigment on nutrient agar and also on cooked potato cylinders. No gas nor acid is formed in any of the sugars called for in the descriptive chart of the Society of American Bacteriologists. The group number given is 21½. 3333823.

Garner, Wolf, and Moss (7) experimented with many types of chemicals and chemical combinations in an attempt to reduce the ravages of this parasite. In no way were they successful in this attempt. They were, however, successful in working out a satisfactory crop rotation which causes a reduction or obliteration of the organism in the soil. Experiments carried on by these workers at Greedmore, N. C. show strikingly that a five year rotation employing corn, wheat, cowpeas, clover, and mixed grasses gives a perfect control. They state that cotton is not susceptible and that it may be used in the rotation if desired. Smith and Godfrey (6,) however, have just shown that certain varieties of cotton are susceptible to this disease in the seedling stage.

THE PHILIPPINE DISEASE

ECONOMIC IMPORTANCE

Solanaceous wilt is the most serious disease of tobacco in the Philippine Islands. It is found throughout the tobacco growing regions and entails a loss annually of from five to fifteen per cent of the crop. Frequently in badly in-

fested soil the loss reaches fifty per cent. The loss is pronounced both on seedlings and old plants but appears most serious when the plants begin to grow after transplanting. In no way is attack restricted to this stage, for mature plants over a meter in height have been observed to develop wilt. In this later type of attack, death does not result from the disease but a permanent wilting of leaves and stunting is noticeable until the plant dies of old age.

Tomatoes and egg-plant are not raised in as great abundance as is tobacco but proportional losses are common. No survey concerning this particular disease has been made in the large gardens in the central part of Luzon but near Manila and in Laguna province, the disease on these two hosts is abundant. A portion of the Experiment Station of the College of Agriculture planted mainly to tomatoes, egg-plant, and tango showed between 70 and 100 per cent of the plants diseased, depending on the host and stage of development. Nearly all of the tomatoes were killed in the seedling stage while egg-plant frequently developed to the fruiting period. No fruit, however, ever matured. Tango was attacked in all stages and resisted destruction until about one third of a meter in height. Scattered seedlings of *Ricinus communis* wilted in all stages of development.

GENERAL DISCUSSION

Conditions have been particularly favorable for the study of solanaceous wilt at the College of Agriculture, because extensive plantings have been made by students on soil heavily infested with the solanaceous wilt organism. The crops represented in the plantings were diverse, thus giving ample opportunity to observe possible hosts and the extent of injury as well as the period of the year most conductive to disease development.

The hosts found susceptible to *Bacterium solanacearum* E. F. S. are, with one exception, those commonly parasitized in the United States. Tomato, tobacco, egg-plant, and castor bean have been seriously parasitized while beans, peanuts, and sweet potatoes which have been found to be susceptible to the disease in the United States are seldom if ever attacked.

On the other hand tango (*Chrysanthemum coronarium* L.), a plant of Chinese origin and used extensively in Chinese communities, appears to suffer severely from the wilt disease.

An enumeration of the plants grown on heavily infested soil will give some idea of those which are not noticeably parasitized by *Bact. solanacearum* E. F. S.

Abelmoschus esculentus (Linn.) Moench., *Arachis hypogaea* Linn., *Canavalia gladiata.*, *Glycine max* (Linn.) Merr., *Hibiscus sabdariffa* Linn., *Ipomoea batatas* (L.) Poir., *Pisum sativum* Linn., *Psophocarpus tetragonolobus* L., *Sesamum indicum* D. C., *Vigna sesquipedalis* Linn.

The comparative susceptibility of tomato and egg-plant to this disease is striking. Wilt is reported as being most prevalent during dry hot weather, its development being hindered by rain and the inherent lower temperature. Observations during the past rainy season do not substantiate this theory in its entirety. Egg-plant showed very slight attack while tomatoes were nearly totally destroyed. Less than one half of one per cent of the egg-plants wilted, while from 80 to 95 per cent of the tomatoes were prostrated before any fruit had developed. On the other hand the egg-plant fruited abundantly.

During the dry season the disease is more serious on egg-plant and causes losses on badly infested soil from 50 to 80 per cent.

Seedlings of castor bean have been under observation only during a semi-wet period. At this time the loss of seedlings was negligible and stunting was frequently observed. Plants over one meter in height showed no symptoms of wilt. No doubt this is due to the stunting caused by the invasion of the bacteria and to the fact that the larger plants develop some degree of resistance.

SYMPTOMS

Tobacco.—Young tobacco seedlings which are attacked by *Bact. solanacearum* first show a slight wilting of one or several leaves. Within twenty-four hours the entire plant has become wilted and the whole growth is prostrated if the stems are not too rigid from woody development. Within the next twenty-four hours the plant becomes dried out. The above periods hold true for the dry season. Tobacco is usually planted during the dry season and is harvested before the wet weather sets in, so the occurrence of the disease on this host during periods of heavy precipitation is a matter of speculation.

The larger plants are frequently attacked by *Bacterium solanacearum*. Death seldom results from such an attack but stunting of growth and a more or less permanent wilting of the leaves to a moderate degree is common. Frequently the foliage turns yellow and dies soon after wilt appears.

When the disease kills or seriously parasitizes a young seedling, the source of the development within the plant may be traced by the browning of the tissues. If cut open, this discoloration appears only in the area which is composed of the vascular elements. (See Plate I, figs. 1 and 2.)

Egg-plant.—Egg-plant seedlings are more resistant to wilt attack than tomato or tobacco. The diseased plants show a wilting of the old outer leaves first, followed within two or three days, by a wilting of the inner leaves and the prostration and death of the entire growth.

The older plants which are attacked, wilt rather slowly and never become prostrate even in most severe cases, for the stems are woody and support the wilted leaves. Frequently fruits become wilted and teem with bacterial cells. (See Plate II, fig. 1.)

Tomato.—Tomato seedlings, especially after transplanting, are very susceptible to attack, and if attacked are a total loss.

Young plants show symptoms of the disease first, by the wilting of a few of the older leaves. Within twenty-four hours if the weather is hot, the entire growth wilts and becomes prostrate. In the rainy season the wilting is prolonged to two or possibly three days duration.

Large plants frequently exhibit one or two branches which have wilted. This is rapidly followed by a complete wilting and prostration of the plant. Fruits are frequently parasitized.

Diseased tomato plants, especially when young and up to the period when woody tissue is laid down in the stems, exhibit brown vascular elements. The progress of the disease may be easily traced because of this peculiar tissue reaction.

Castor bean.—The wilt of castor bean is recognized by the same characteristic reactions to the organism as the wilt of the first mentioned host plants. Usually the diseased plants are slightly smaller after attack than those free from the disease. The outer large leaves seem to suffer first while the small central leaves resist until the outer ones are entirely wilted and perhaps shed. No plants over one meter is height have been observed with the disease.

Vascular elements show a slight browning but they are not so noticeable as in the case of the solanaceous plants. (See Plate III, figs. 1 and 2.)

Tango.—The study of the wilt disease of tango has not been sufficiently carried out, at present, to warrant any absolute statement as to the causal organism. The organism responsible for the wilt is a bacterial rod which produces a pigment and causes a discoloration of media, especially of nutrient agar and potato cylinders. The color while it is brown is not so deep as that produced by the organism from tobacco, egg-plant, tomato or castor bean. Cross inoculations have not been possible, but work is progressing now which should produce results in a short time. (See Plate II, fig. 2.)

For the present the disease of tango will be considered to be caused by *Bact. solanacearum* E. F. S.

The wilt develops in the old leaves first, spreading rapidly to the younger ones. Because of the largeness of the stem, the plant is never prostrated but appears as a tall leafless, leaf-scarred stem. So far observations have been confined to the dry season as the host plant is not commonly grown during periods of heavy rains.

The discoloration of the vascular bundles in the younger plants is as pronounced as in tomato or tobacco seedlings.

CAUSAL ORGANISM

The organism causing the wilt of tobacco, tomato, egg-plant, and castor bean has been identified as *Bact. solanacearum* E. F. S. by extensive physiological studies.

The organism which is the cause of the wilt of tango has been grown on most of the media called for in the descriptive chart of the Society of American Bacteriologists and has been found to give the same characteristic growths as *Bact. solanacearum* E. F. S. except in depth of the brownish pigment. The cultural work to date gives the following cultural number: 2—, 3333823, which is identical with Smith's report on *Bact. solanacearum.*

CONTROL

Several control experiments were carried on in Los Baños, but results were all negative. The following chemicals were applied to soil in varying amounts; copper sulphate, calcium oxide, calcium phosphate, and potassium chloride.

The lime, potash, and nitrogen compounds stimulated growth but failed to give any degree of control.

The only absolute method of control is that recommended by Garner, Wolf, and Moss, (2) namely, a five year crop rotation in which all hosts of *Bact. solanacearum* E. F. S. are kept from the infested soil.

An exception to this method of control is the planting of egg-plant during the seasons when the amount of precipitation is maximum. This does not

hold true with tomato or castor bean for both of these hosts wilted profusely during periods of heavy rains. No doubt the disease on the last two plants is reduced, but not enough to act as a controlling factor.

SUMMARY

1. *Bacterium solanacearum* E. F. S. causes the most serious disease of solanaceous plants such as tomato, tobacco, and egg-plant, known in the Philippine Islands.

2. Egg-plant appears somewhat resistant to attack and can be grown successfully without much loss due to this malady, if planted during the rainy season so that maturity will be reached by December first.

3. A description of the disease on tomato, tobacco, egg-plant and castor bean is given.

4. Tango (*Chrysanthemum coronarium*,) a plant of Mediterranean origin, is seriously attacked by an organism very similar to *Bact. solanacearum* E. F. S. if not identical with it. The organism from tango does not produce so dark a pigment as the organism isolated from wilted solanaceous plants or castor bean.

5. A list of plants not visibly susceptible to *Bact. solanacearum* E. F. S. is appendaged.

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ILLUSTRATIONS

Plate I

Fig. 1. Healthy tobacco plants at the beginning of the dry season. Very few plants wilted previously to this time.

Fig. 2. Partially wilted tobacco plant.

Plate II

Fig. 1. Mature egg-plant grown during the rainy season. Less than one tenth of one per cent of the plants during this period were diseased.

Fig. 2. Healthy and diseased tango seedlings. The wilted plant was inoculated six days previous to the taking of the photograph.

Plate III

Fig. 1. Wilted castor bean seedling in the field.

Fig. 2. (1) Wilted castor bean seedling and (2) castor bean seedling dwarfed by bacterial attack. Fifty centavo piece at the left. Other plants of the same age were over one half meter in height.

Figure 1.

Figure 2.

PLATE I.

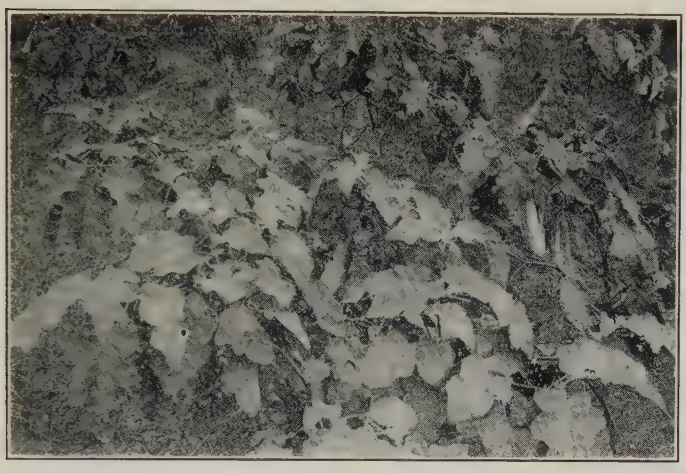

Figure 1.

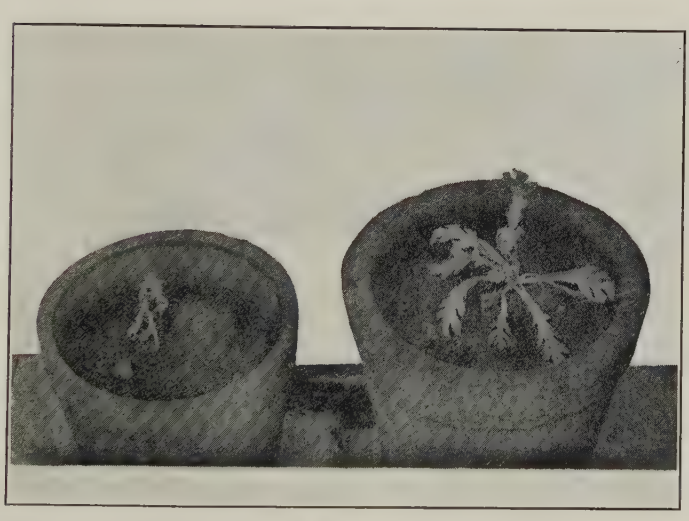

Figure 2.

PLATE II.

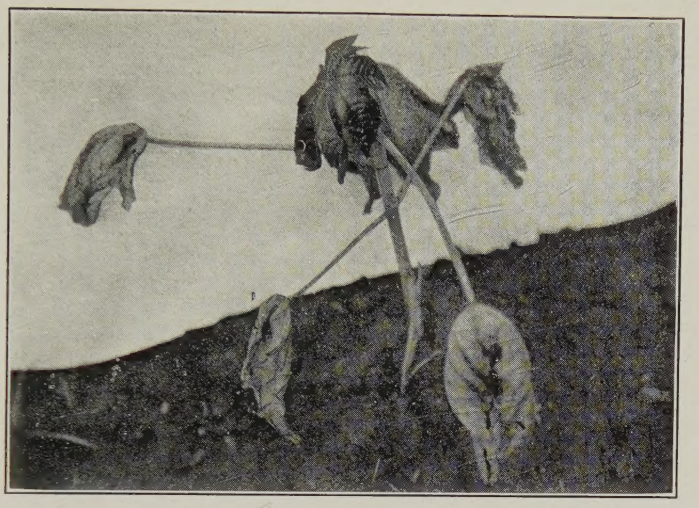

Figure 1.

(1) (2)

Figure 2.

PLATE III.

ABSTRACT[1]

The effect of season upon the culture of roselle, SEVERO G. YAP (*Thesis presented for graduation from the College of Agriculture, No. 137; Experiment Station contribution, No. 80*).—The value of roselle as a fruit is beginning to be recognized in the Philippines as in other tropical countries. It is a promising crop, if planted in season. Hence, the determination of the best season for planting roselle for fruit bearing is of prime importance to farmers. Mr. Yap carried out an experiment to find the best time for planting roselle at the College of Agriculture, Los Baños.

The varieties of roselle used were C. A. 12415 Victor, C. A. 12462 Archer, and C. A. 12463 Rico. The author began his planting in April and continued it till December. The results of his culture from April to September were the only ones tabulated. The later cultures were not worthy of note.

From the results of the experiments, it was seen in the later plantings that there was a decrease in the average number of days from planting to maturity of first fruits. As regards this condition the author says: "The probable explanation of the decrease in the number of days per month from planting to maturity of first fruits is that the flowering season of roselle in this locality was found to commence about the middle of October, in which case the plants cultured nearer the month of October fruited earlier in spite of their less developed stems and branches."

It was found that in the average weight of fruit per plant, the Archer led the others, exceeding the Victor by 0.14 kilograms and the Rico by 0.27 kilograms.

Mention is made of disease and pests. The blight of roselle caused by *Phoma sabdariffae* Sacc. injured the young plants. But spraying the plants either with Bordeaux Mixture or Burgundy Mixture proved to be beneficial.

The writer summarized the results of his experiments as follows:

1. High yield with large fruit was obtained from plants cultured during April, May, and June.

2. The average number of days required by the fruit to mature after flowering, increased gradually with the lateness of planting.

3. The average number of days from planting to maturity of first fruit decreased with the lateness in the season of planting because the fruiting season was the same for all cultures.

4. The yield of fruit also decreased with the lateness of planting.

5. Late plantings, as in October, November, and December did not yield good crops.

To this abstract may be added this comment, by Professor Higgins, the author's thesis adviser.

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[1] Abstract prepared as part of theme work in English 4, College of Agriculture.

The practical suggestion that grows out of this investigation is, that roselle should be planted as early as possible after April 1, if sufficient moisture is available to carry the plants through April and May in a thriving condition. The rainfall in this part of the Philippines is not sufficient but with irrigation two months growth and correspondingly increased yield may thus be gained over June plantings. If it is not possible to apply water to the field, time may be gained by planting the seed during April in boxes or in a protected seed bed and transplanting to the permanent location when the dry season has passed. This is the practice which the author followed with those which he designated the 'April cultures.'

It will be observed that in these investigations, no plantings were made earlier than April 16. No data are available therefore to show how much earlier it may be possible to plant where water is available for irrigation.

Abstract by Julian Agati.